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DEMOGRAPHIC MONITORING OF THREE SPECIES
OF BOTRYCHIUM (OPHIOGLOSSACEAE)
IN WATERTON LAKES PARK, ALBERTA
1993 Progress Report

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INTRODUCTION

Moonworts (Botrychium subgenus Botrychium) are a group of small, nonvascular plants in the Family Ophioglossaceae with a center of distribution in western North America (Wagner et al. 1984). Plants consist of a single frond divided into a sterile, leaf-like segment below a fertile, spore-bearing segment. Many of the species are difficult to find and are considered rare (Lellinger 1985). Among these is B. paradoxum, a candidate for listing as a threatened or endangered species by the U.S. Fish and Wildlife Service. This plant is currently known from a handful of sites in Alberta, Montana and Utah (Wagner and Wagner 1981, Lellinger 1985, W.H. Wagner pers. com.). This species is unusual in that the sterile segment of the frond is replaced by a second fertile segment.

In Montana and Alberta B. paradoxum has often been found growing with other species of moonworts, and the question of whether B. paradoxum is a good species or simply an unusual form of other more common species has been raised. In Waterton Park, Alberta, B. paradoxum occurs with B. hesperium and their putative hybrid B. X watertonense. Analysis of flavonoid chemistry between B. paradoxum and B. hesperium was performed and nearly half (9) of the 20 compounds examined were unique to one of the two species (Wagner et al. 1984). These results support the contention that B. paradoxum is a valid species but are not entirely convincing because the distribution of secondary metabolites such as flavonoids in tissues may be partially under environmental or developmental rather than strictly genetic controls. More powerful molecular techniques such as isozyme electrophoresis and DNA analysis have not yet been performed because of the difficulty in obtaining material (W. Hauk pers. com.). Direct observation of many individuals over a period of years will help to determine whether B. paradoxum is a stable genetic species or merely an aberrant phenotype of another species.

Due to their small size and rarity, relatively little is known about the life history and ecology of moonworts. Lellinger (1985) states that moderate disturbance such as grazing seems to favor their establishment and continued survival. It is not known how long-lived the plants are or whether or not they produce a frond each year. Wagner (pers. com.) suggests that some populations may be ephemeral while others may persist for centuries. Observation of individual plants through time will help to answer these questions.

The purpose of our study is to track morphological characters of individual moonwort plants over a period of many years in order to: (1) determine basic life history and population parameters such as average life expectancy and mean age for B. paradoxum and B. hesperium and (2) gather evidence to

support or reject the hypothesis that B. paradoxum is not a true species but an aberrant phenotype of B. hesperium and/or other species of Botrychium. This report summarizes results from the first five years of the study.

METHODS

Study Site

We conducted our study in the Red Rock Canyon area of Waterton Lakes National Park ca. 12 km northwest of the town of Waterton. The study site is located on the north side of Bauerman Creek ca. 50 m northwest of the footbridge and ca. 200 m southwest of the Red Rock parking and picnic area. Elevation of the site is ca. 1555 m. The compass bearing from the site to the uppermost outhouse along the creek is 139 degrees. The compass bearing from the site to the top of Anderson Peak is 270 degrees.

The vegetation of the area is lodgepole pine (Pinus contorta) and spruce (Picea engelmannii) forest interspersed with meadows dominated by rough fescue (Festuca scabrella), Idaho fescue (F. idahoensis) and shrubby cinquefoil (Potentilla fruticosa) on hilltops and warm exposures. Our study site is in one of these meadows.

Field Procedures

We established two parallel belt transects at the study site. The upper (north) consists of eight adjacent 1-m² plots, and the lower (south) consists of five plots. The start and end points of the transects were permanently marked by driving 1/2 inch diameter reinforcing bar into the ground. These marker pins were painted orange to aid relocation. Individual Botrychium plants were mapped following methods outlined in Lesica (1987). For each plant we recorded the following morphological characters:

Species (P = paradoxum, W = watertonense, H = hesperium)

Degree of pinnation of sporophore (P1 = once pinnate, P2 = twice pinnate etc.)

Above ground height (H12 = a plant 12 mm tall from ground level to tip of longest sporophore branch)

Length of sporophore (L10 = a plant with a fertile segment 10 mm long)

Thus a plant scored as H-P2-H20-L14 is morphologically identified as B. hesperium 20 mm tall with a twice-pinnate sporophore 14 mm long. Species were identified using the criteria presented in

Wagner et al. (1984). Beginning in 1990 we also recorded the length and degree of pinnation of the sterile frond segment.

In 1991 plants were too dense to map in portions of plots 3 and 4 in the upper line. These areas have been eliminated from the analysis.

Data Analysis

We found that some plants would go undetected for one or more years but reappear in subsequent years. The presence of underground plants can be inferred by comparing transect maps from the full sequence of years. We recorded these plants as "U." The proportion of underground plants ranged from 3-20% in 1991-92 among the three species. In 1990-91 among the three species, 93% of the plants stayed underground for only one year. Thus, we have chosen to eliminate the first and last years of the study from demographic analysis. Montgomery (1990) reported that plants of Botrychium dissectum would often be "missing" for one or two years before appearing again.

Mortality is the proportion of the plants present in year t that died between years t and $t+1$. Recruitment is the proportion of plants present in year t that were new recruits. Statistical significance of mortality and recruitment proportions among species were compared with an overall chi-square goodness of fit test. If a 2 X 3 test showed a significant result, we used 2 X 2 tests to determine which pairs of sites were different. Probability values were not corrected for multiple tests. We employed an α -level of 0.05.

RESULTS

No plants "changed species" during the four years of the study. The few plants that we previously reported as changing from one species to another were based on misidentifications.

Sample population sizes in 1990-92 were relatively stable; all three species had slightly more plants in 1992 compared to 1990 (Fig. 1). Survivorship of the 1989 sample population was highest for Botrychium hesperium, lowest for B. paradoxum and intermediate for B. watertonense (Fig. 2). Mortality was higher in B. paradoxum compared to B. hesperium for all three years measured, and this difference was statistically significant in two of those years (chi-square test, $P < 0.05$; Fig. 3). Mortality in B. watertonense was more variable than the other two species, as high as B. paradoxum in one year and lower than B. hesperium another (Fig. 3). Recruitment among the three species showed a pattern very similar to mortality. Recruitment was higher in B. paradoxum, and this difference was statistically different in two of the three years (Fig. 4). Recruitment proportion for B.

watertonense was higher than B. paradoxum in one year but lower than B. hesperium in the two other years (Fig. 4).

DISCUSSION

We have obtained no evidence that would indicate that Botrychium paradoxum and B. watertonense are anything but morphologically stable species.

The shape of the depletion curves for all three species suggests that they are short-lived perennials. However, it should be kept in mind that plants may exist underground as gametophytes for a period of time before emerging as a mature sporophyte. Nonetheless, compared to Botrychium dissectum, all three species are short lived (Montgomery 1990). The high rates of mortality and recruitment demonstrated by these three species of Botrychium suggest that they are adapted to occupying early successional sites or ephemeral gaps in more stable vegetation (MacArthur and Wilson 1967, Harper 1977, Solbrig and Solbrig 1979). Botrychium paradoxum has the highest rates of mortality and recruitment, indicating that it has the most volatile demographic regime and suggest that of all three species, it is the most adapted to ephemeral habitats and is the most prone to cycles of extinction and recolonization (Diamond 1984, Pimm et al. 1988).

Botrychium hesperium is longer lived and had lower levels of recruitment and mortality for all years measured compared to B. paradoxum. These differences in life history must be at least partially genetically determined since the two populations are growing in the same environment. Hybridization may result in the breakup or restructuring of coadapted gene complexes, and breakup of integrated genetic systems often results in increased additive genetic variation (Carson 1975, Templeton 1980). Morphological and chemical evidence indicates that B. watertonense is a hybrid between these two species (Wagner et al. 1984). The life history characteristics of the hybrid plants are more variable and encompass more than the range of either of the putative parent species. Our results provide evidence that balanced genetic systems interacting with environment to produce life history traits in the parent Botrychium species have been disrupted in the hybrid.

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Figure 1. Number of Botrychium hesperium, B. paradoxum and B. watertonense plants in sample populations in 1990-92.

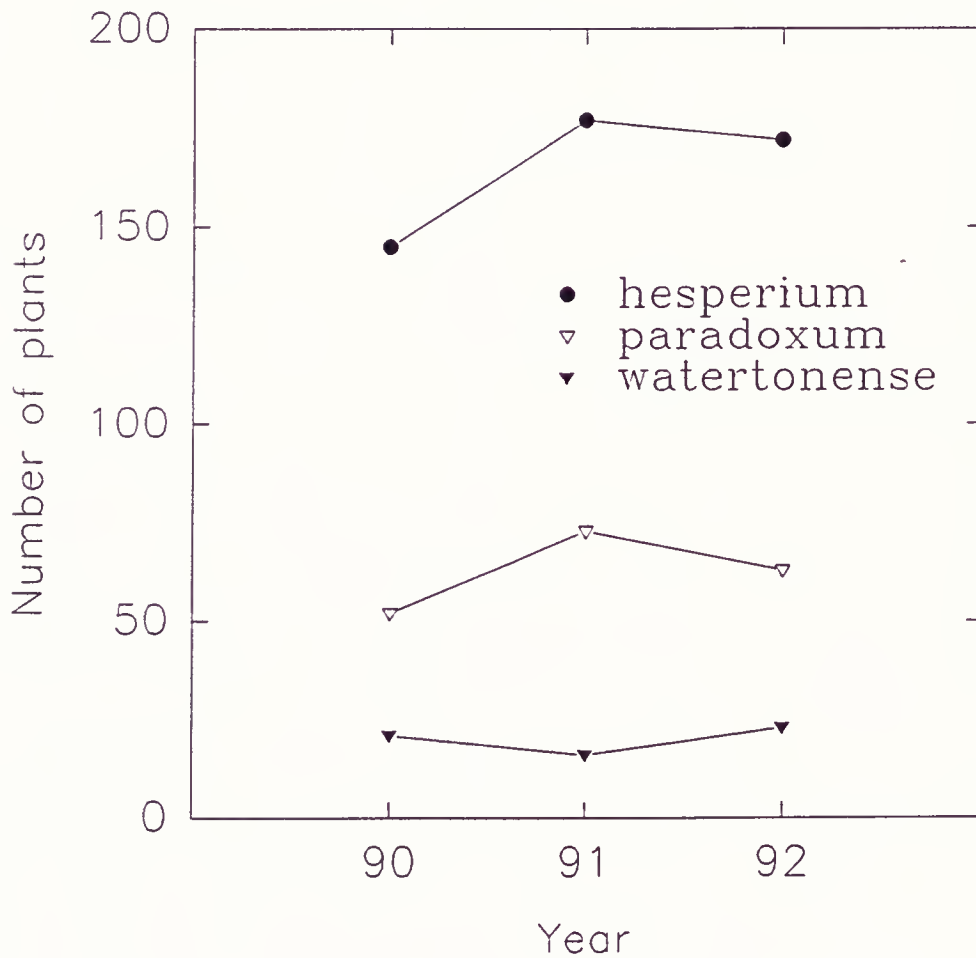


Figure 2. Depletion curve for 1989 sample populations of Botrychium hesperium, B. paradoxum and B. watertonense.

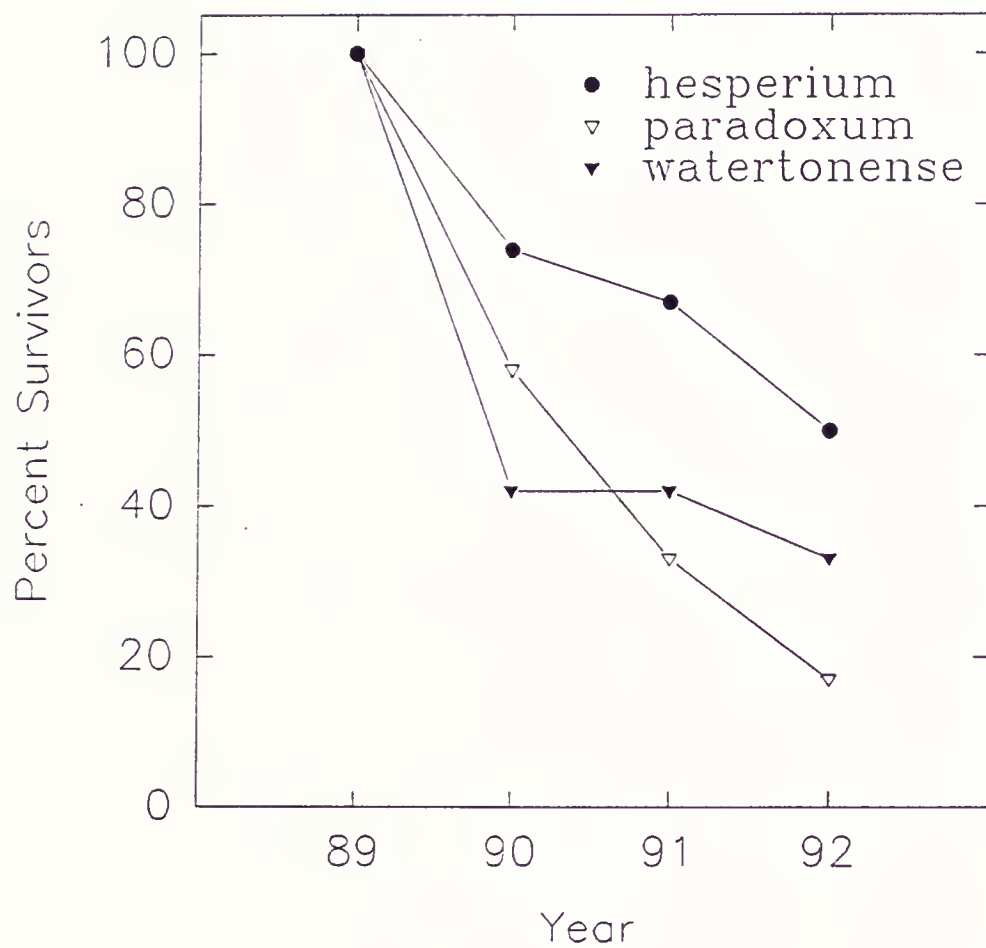


Figure 3. Proportion of plants dying in three consecutive 1-years intervals for Botrychium hesperium, B. paradoxum and B. watertonense populations. For each interval, values annotated by different letters are significantly different by chi-square tests ($P < 0.05$, see Methods).

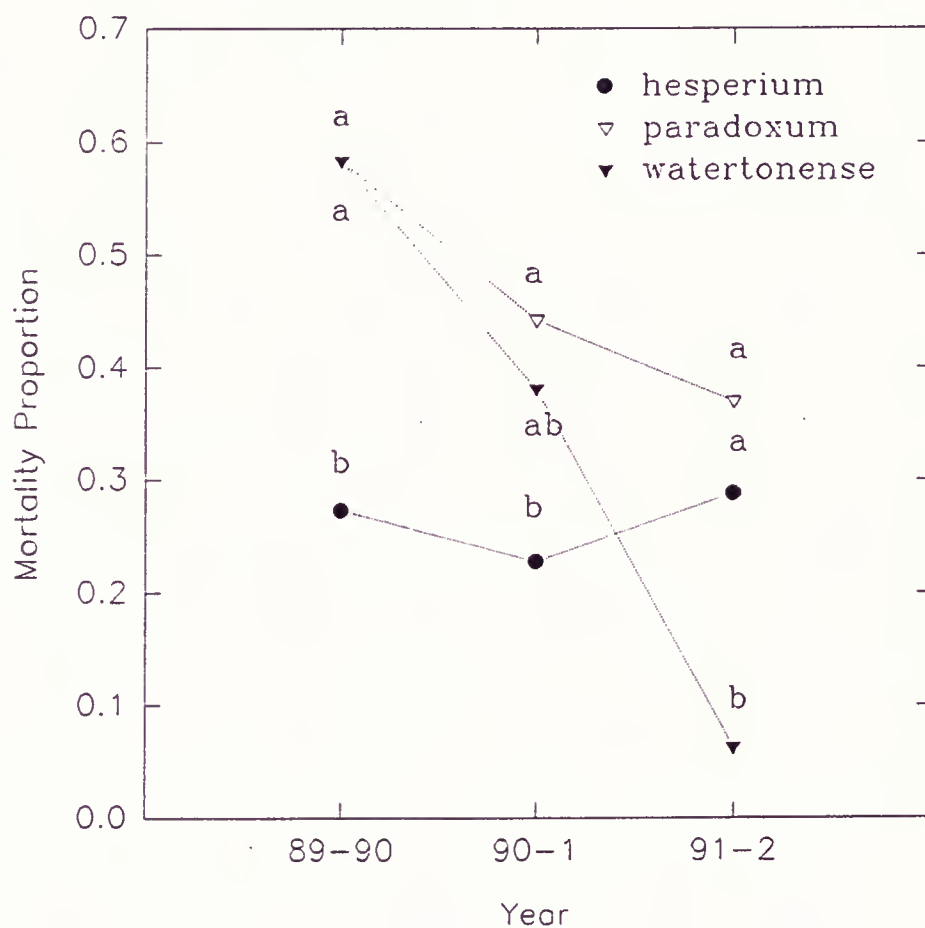
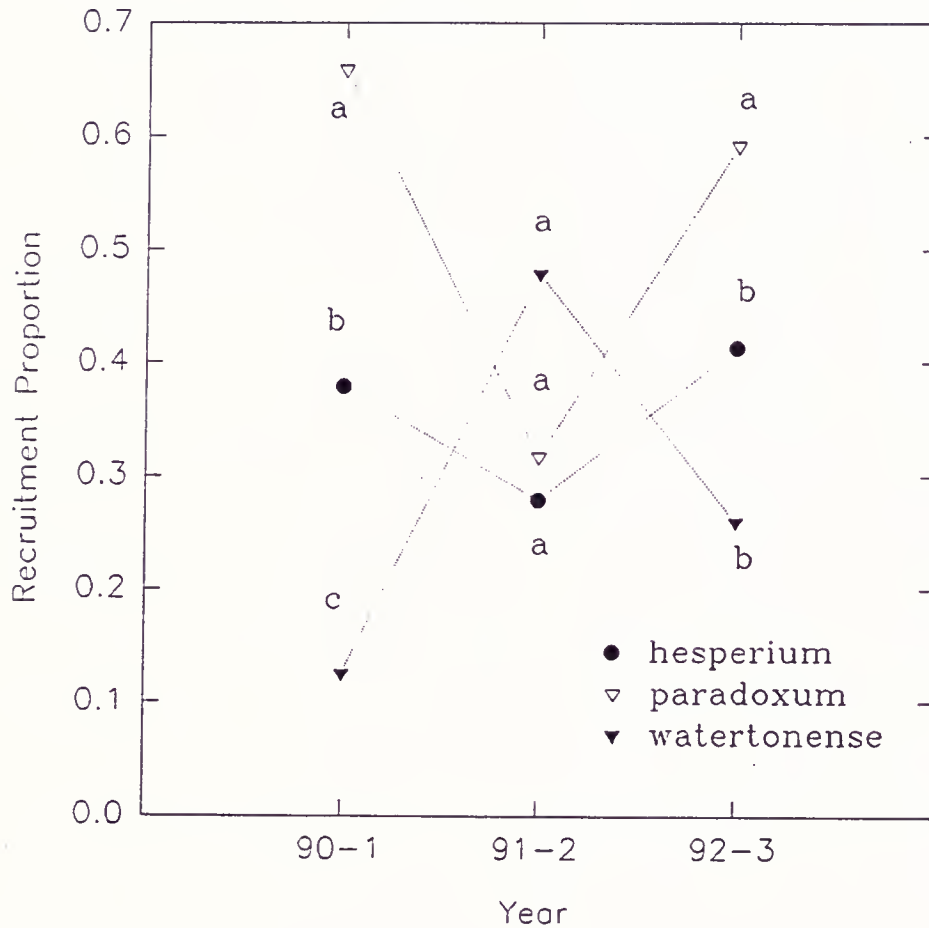


Figure 4. Proportion of new recruits in three consecutive 1-years intervals for Botrychium hesperium, B. paradoxum and B. watertonense populations. For each interval, values annotated by different letters are significantly different by chi-square tests ($P < 0.05$, see Methods).



Appendix A. Morphological codes for individual Botrychium plants in permanent monitoring transects in 1989-93. See text for explanation of codes.

	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>	<u>1993</u>
			Lower Line		
Plot 1					
a	H-P2-H30-L11	H-P2-H39-L17	H-P2-H54-L20	--	--
b	H-P3-H71-L38	H-P2-H85-L35	--	--	--
c	H-P1-H19-L10	H-P1-H30-L17	H-U	H-P1-H24	--
d	H-P1-H24-L10	H-U	H-P2-H38-L11	H-P1-H12	H-P1-H19
e	H-P1-H26-L10	H-P1-H34-L14	H-P1-H26-L11	--	--
f	P-P1-H51-L15	P-P1-H60-L12	P-P1-H61-L16	P----H51	P----H81
g	--	H-P2-H25-L11	H-U	H-P1-H20	H-P1-H50
h	--	H-P1-H15-L18	--	--	--
i	--	P-P1-H13-L08	--	--	--
j	--	H-P2-H50-L24	H-P--H13-L--	--	--
k	--	H-P2-H70-L31	H-P2-H56-L16	H-P1-H40	H-P2-H89
l	--	H-P1-H60-L15	--	--	--
m	--	H-P2-H54-L17	H-P2-H45-L14	--	--
n	--	H-P1-H37-L13	H-P2-H49-L21	H-P1-H24	H-P1-H40
o	--	H-P2-H32-L12	H-P1-H29-L11	H-U	H-P1-H27
p	--	H-P1-H21-L03	H-P1-H15-L06	H-U	H-P1-H38
q	--	H-P1-H16-L08	--	--	--
r	--	P-P1-H27-L06	P-P1-H18-L03	P-U	P----H26
s	--	P-P1-H28-L10	P-U	P----H45	P----H62
t	--	P-P1-H31-L09	--	--	--
u	--	H-P1-H32-L11	H-P2-H38-L13	H-P1-H25	H-P1-H29
v	--	H-P2-H60-L22	--	--	--
w	--	H-P2-H50-L20	H-P3-H81-L29	H-P2-H61	H-P2-H79
x	--	H-P1-H22-L07	H-P2-H41-L21	H-P2-H38	H-P2-H60
y	--	P-P2-H100-L35	P-P1-H79-L19	--	--
z	--	P-P1-H55-L12	P-P1-H73-L28	P----H54	P----H95
aa	--	P-P1-H45-L11	P-U	P----H59	P----H103
bb	--	P-P1-H52-L15	--	--	--
cc	--	--	H-P2-H45-L10	--	--
dd	--	--	P-P1-H20-L0	--	--
ee	--	--	P-P1-H49-L11	P-U	P----H56
ff	--	--	P-P2-H81-L22	--	--
gg	--	--	H-P2-H51-L15	H-P1-H21	H-P1-H37
hh	--	--	H-P2-H50-L16	--	--
ii	--	--	H-P2-H53-L20	H-U	H-P1-H46
jj	--	--	H-P2-H50-L18	H-P1-H42	H-P1-H50
kk	--	--	H-P2-H63-L15	H-P1-H32	H-P1-H40
ll	--	--	H-P2-H38-L19	--	--
mm	--	--	H-P1-H31-L08	--	--
nn	--	--	H-P1-H24-L08	H-P1-H16	H-P1-H32
oo	--	--	H-P1-H25-L11	--	--
pp	--	--	--	H-P1-H44	--
qq	--	--	--	H-P1-H23	H-P1-H49
rr	--	--	--	H-P1-H11	--
ss	--	--	--	H-P2-H56	H-P1-H104
tt	--	--	--	H-P1-H09	--
uu	--	--	--	H-P1-H35	--
vv	--	--	--	H-P1-H16	H-P1-H48
ww	--	--	--	--	P----H42
xx	--	--	--	--	P----H51
yy	--	--	--	--	P----H55
zz	--	--	--	--	P----H53
aaa	--	--	--	--	H-P1-H46
bbb	--	--	--	--	H-P1-H37
ccc	--	--	--	--	H-P2-H65

ddd	--	--	--	--	H-P1-H20
eee	--	--	--	--	H-P1-H25
fff	--	--	--	--	P----H42
ggg	--	--	--	--	P----H41
hhh	--	--	--	--	P----H37
iii	--	--	--	--	P----H26
jjj	--	--	--	--	H-P1-H28
kkk	--	--	--	--	H-P1-H15
lll	--	--	--	--	H-P1-H36
mmm	--	--	--	--	H-P1-H40

Plot 2

a	P-P1-H63-L22	P-U	P-P1-H22-L06	P----H27	--
b	H-P1-H35-L15	--	--	--	--
c	P-P1-H55-L17	--	--	--	--
d	P-P1-H62-L25	--	--	--	--
e	P-P1-H29-L05	P-P1-H40-L70	--	--	--
f	H-P1-H21-L08	--	--	--	--
g	H-P1-H37-L10	H-P2-H40-L19	H-U	H-U	H-P1-H21
h	--	H-P1-H38-L09	H-P2-H46-L03	H-U	H-P2-H80
i	--	P-P1-H67-L20	P-P1-H67-L16	--	--
j	--	P-P1-H53-L16	P-P1-H26-L10	--	--
k	--	H----H40-L--	H-U	H-U	H-P2-H70
l	--	H-P1-H25-L05	H-P1-H26-L05	--	--
m	--	H-P1-H33-L04	H-P2-H41-L11	--	--
n	--	H-P1-H24-L05	H-P1-H22-L04	H-U	H-P1-H55
o	--	H-P1-H20-L08	H-P1-H28-L11	--	--
p	--	H-P1-H35-L09	--	--	--
q	--	P-P1-H38-L07	P-U	P-U	P----H40
r	--	P-P1-H14-L03	--	--	--
s	--	H-P2-H45-L21	--	--	--
t	--	H-P1-H21-L08	H-P1-H24-L06	H-U	H-P1-H36
u	--	P-P1-H45-L07	--	--	--
v	--	P-P2-H94-L22	P-U	P-U	P----H67
w	--	H-P2-H41-L16	H-P2-H46-L13	--	--
x	--	H-P2-H45-L13	H-U	H-P1-H25	H-P2-H62
y	--	P-P2-H110-L35	P-P2-H90-L25	P-U	P----H60
z	--	P-P1-H70-L19	P-P1-H55-L12	--	--
aa	--	P-P1-H52-L12	--	--	--
bb	--	--	P-P1-H25-L05	P-U	P----H50
cc	--	--	H-P1-H21-L04	--	--
dd	--	--	P-P1-H32-L05	--	--
ee	--	--	H-P2-H46-L03	H-U	H-P1-H60
ff	--	--	P-P2-H50-L22	--	--
gg	--	--	H-P2-H41-L20	H-U	H-P2-H79
hh	--	--	H-P1-H11-L09	H-U	H-P1-H36
ii	--	--	P-P2-H61-L18	P-U	P----H95
jj	--	--	P-P1-H13-L10	--	--
kk	--	--	P-P1-H14-L07	P----H22	--
ll	--	--	H-P1-H10-L01	--	--
mm	--	--	H-P1-H25-L04	--	--
nn	--	--	H-P1-H28-L08	--	--
oo	--	--	H-P1-H22-L08	H-U	H-P1-H27
pp	--	--	H-P1-H33-L18	H-P1-H25	--
qq	--	--	--	W-P1-H40	--
rr	--	--	--	H-P1-H38	H-P2-H73
ss	--	--	--	H-P1-H37	H-P1-H47
tt	--	--	--	--	H-P1-H19
uu	--	--	--	--	P----H44
vv	--	--	--	--	H-P1-H30
ww	--	--	--	--	H-P1-H53
xx	--	--	--	--	P----H59

yy	--	--	--	--	P----H80
zz	--	--	--	--	P----H35
aaa	--	--	--	--	H-P1-H38
bbb	--	--	--	--	H-P1-H37
ccc	--	--	--	--	H-P1-H55
ddd	--	--	--	--	H-P2-H52
eee	--	--	--	--	H-P1-H35
fff	--	--	--	--	H-P1-H39
ggg	--	--	--	--	H-P1-H30
hhh	--	--	--	--	H-P1-H64
iii	--	--	--	--	P----H58

Plot 3

a	--	H-P1-H40-L10	H-P1-H20-L05	--	--
b	--	P-P1-H65-L10	--	--	--
c	--	P-P2-H43-L16	P-P1-H73-L20	--	--
d	--	P-P1-H41-L14	--	--	--
e	--	--	P-P1-H50-L12	--	--
f	--	--	P-P1-H33-L12	P-U	P----H29
g	--	--	P-P1-H29-L09	P-U	P----H39
h	--	--	P-P1-H24-L05	--	--
i	--	--	P-P1-H56-L10	P----H17	--
j	--	--	P-P1-H32-L08	P----H35	--
k	--	--	P-P1-H64-L09	P----H45	--
l	--	--	P-P1-H31-L13	--	--
m	--	--	--	P----H45	P----H65
n	--	--	--	--	P----H81
o	--	--	--	--	P----H57
p	--	--	--	--	P----H22
q	--	--	--	--	P----H75
r	--	--	--	--	P----H88
s	--	--	--	--	P----H70
t	--	--	--	--	P----H76
u	--	--	--	--	P----H66
v	--	--	--	--	P----H99
w	--	--	--	--	P----H19
x	--	--	--	--	P----H43

Plot 4

a	P-P1-H63-L23	P-P2-H76-L30	--	--	--
b	H-P1-H37-L10	H-P2-H60-L23	H-P2-H71-L31	--	--
c	--	H-P1-H36-L07	--	--	--
d	--	H-P1-H62-L21	H-U	H-P1-H38	H-P1-H71
e	--	H-P2-H61-L16	H-P2-H53-L15	H-P1-H43	H-P1-H44
f	--	P-P1-H60-L14	P-U	P----H45	--
g	--	P-P2-H40-L15	P-U	P-U	P----H50
h	--	P-P1-H17-L06	P-P1-H23-L08	--	--
i	--	H-P2-H32-L22	H-P2-H75-L40	H-P2-H57	H-P2-H66
j	--	P-P1-H44-L16	--	--	--
k	--	H-P2-H69-L25	H-P2-H68-L31	H-P1-H72	H-P2-H112
l	--	P-P1-H28-L05	--	--	--
m	--	H-P2-H35-L10	--	--	--
n	--	--	P-P1-H28-L08	P-U	P----H20
o	--	--	P-P1-H40-L06	P-U	P----H30
p	--	--	P-P1-H62-L18	P-U	P----H30
q	--	--	P-P1-H31-L09	P-U	P----H44
r	--	--	P-P1-H90-L19	P-U	P----H40
s	--	--	P-P1-H45-L06	P-U	P----H33
t	--	--	H-P2-H70-L28	--	--
u	--	--	P-P1-H70-L20	--	--
v	--	--	P-P1-H30-L10	P----H62	P----H82
w	--	--	H-P1-H29-L10	--	--

x	--	--	H-P1-H40-L06	--	--
y	--	--	P-P1-H65-L01	P----H26	--
z	--	--	P-P1-H41-L06	--	--
aa	--	--	H-P1-H77-L18	--	--
bb	--	--	P-P1-H41-L12	--	--
cc	--	--	--	H-P1-H40	H-P2-H59
dd	--	--	--	P----H32	--
ee	--	--	--	H-P1-H10	H-P1-H20
ff	--	--	--	P----H67	--
gg	--	--	--	P----H22	P----H22
hh	--	--	--	H-P1-H22	H-P1-H45
ii	--	--	--	H-P1-H27	--
jj	--	--	--	H-P1-H40	--
kk	--	--	--	--	P----H32
ll	--	--	--	--	P----H82
mm	--	--	--	--	H-P1-H30
nn	--	--	--	--	P----H30
oo	--	--	--	--	P----H75
pp	--	--	--	--	P----H61
qq	--	--	--	--	P----H40
rr	--	--	--	--	P----H45
ss	--	--	--	--	P----H41
tt	--	--	--	--	P----H18
uu	--	--	--	--	P----H16
vv	--	--	--	--	H-P1-H24
ww	--	--	--	--	P----H50
xx	--	--	--	--	P----H17
yy	--	--	--	--	P----H19
zz	--	--	--	--	P----H25

Plot 5

a	P-P1-H60-L17	P-U	P-P1-H75-L16	--	--
b	P-P1-H30-L08	--	--	--	--
c	P-P1-H31-L05	P-U	P-P1-H11-L01	--	--
d	H-P2-H76-L40	H-P1-H37-L15	H-U	H-P1-H40	--
e	H-P2-H26-L06	H-P2-H40-L15	H-U	H-P1-H31	H-P1-H31
f	H-Juvenile	H-P2-H38-L17	H-P2-H50-L09	H-U	H-P2-H57
g	W-P1-H45-L12	W-U	W-P1-H64-L18	W-P1-H45	W-P2-H72
h	H-P2-H42-L14	--	--	--	--
i	H-P1-H38-L15	H-P2-H42-L16	H-U	H-P2-H48	H-P3-H91
j	H-P2-H50-L20	H-P1-H26-L04	H-P1-H46-L06	--	--
k	H-P2-H52-L21	H-P2-H54-L22	H-P1-H30-L11	--	--
l	H-P2-H47-L22	H-P2-H50-L25	H-U	H-P1-H18	H-P1-H42
m	H-P1-H11-L08	--	--	--	--
n	--	H-P1-H30-L08	H-P1-H34-P08	--	--
o	--	H-P1-H29-L04	H-P1-H32-L08	H-P1-H33	H-P1-H32
p	--	P-P2-H59-L16	P-P2-H61-L17	--	--
q	--	H-P2-H68-L36	H-U	H-P1-H38	H-P1-H53
r	--	P-P1-H58-L07	P-U	P-U	P----H59
s	--	P-P1-H40-L09	P-P1-H27-L03	P----H17	P----H52
t	--	P-P1-H20-L03	--	--	--
u	--	P-P1-H49-L10	--	--	--
v	--	P-P1-H31-L09	--	--	--
w	--	P-P2-H50-L16	--	--	--
x	--	H-P2-H77-L30	H-P2-H65-L18	H-P2-H41	--
y	--	H-P1-H30-L06	--	--	--
z	--stem 1	H-P1-H19-L06	H-P2-H49-L24	H-P1-H27	H-P1-H49
aa	--stem 2	H-P2-H32-L08	H-P1-H11-L03	H-P2-H53	H-P1-H42
bb	--	W-P1-H61-L18	W-U	W-P1-H41	W-P1-H52
cc	--	--	P-P1-H47-L11	--	--
dd	--	P-P1-H31-L06	--	--	--
ee	--	H-sterile leaf	H-P1-H12-L03	H-P1-H21	H-P2-H52

ff	--	H-P2-H56-L26	H-P2-H48-L28	--	--
gg	--	H-P3-H80-L31	H-P2-H72-L32	H-P1-H22	H-P2-H57
hh	--	P-P1-H36-L06	P-P1-H10-L02	--	--
ii	--	H-P1-H35-L08	--	--	--
jj	--	--	P-P1-H29-L03	--	--
kk	--	--	H-P1-H31-L06	--	--
ll	--	--	P-P1-H18-L04	P-----H62	P-----H70
mm	--	--	P-P1-H40-L07	P-U	P-----H40
nn	--	--	H-P1-H30-L10	--	--
oo	--	--	H-P1-H22-L10	H-P1-H35	H-P1-H65
pp	--	--	P-P1-H53-L18	--	--
qq	--	--	P-P1-H53-L18	P-U	P-----H67
rr	--	--	--	P-----H47	--
ss	--	--	--	H-P1-H40	--
tt	--	--	--	H-P1-H32	--
uu	--	--	--	H-P1-H27	H-P1-H33
vv	--	--	--	H-P1-H21	H-P1-H43
ww	--	--	--	P-----H89	P-----H86
xx	--	--	--	P-----H47	--
yy	--	--	--	--	H-P1-H16
zz	--	--	--	--	P-----H104
aaa	--	--	--	--	P-----H27
bbb	--	--	--	--	P-----H56
ccc	--	--	--	--	H-P1-H29
ddd	--	--	--	--	W-P1-H40
eee	--	--	--	--	P-----H23
fff	--	--	--	--	W-P1-H43
ggg	--	--	--	--	H-P2-H63
hhh	--	--	--	--	H-P2-H65
iii	--	--	--	--	H-P1-H32

Upper Line

Plot 1

a	W-P2-H55-L17	W-P2-H68-L27	W-P1-H47-L14	--	--
b	H-P2-H57-L35	--	--	--	--
c	--	H-P2-H65-L30	H-P2-H65-L24	--	--
d	--	W-P1-H68-L18	W-P1-H39-L13	W-P1-H58	W-P1-H80
e	--	H-P2-H80-L26	H-U	H-P1-H35	H-P10-H65
f	--	H-P3-H89-L53	--	--	--
g	--	H-P1-H35-L08	H-P2-H67-L34	H-P2-H66	H-P2-H87
h	--	W-P2-H60-L21	W-P2-H76-L23	W-P1-H53	W-P2-H113
i	--	W-P3-H70-L29	W-P2-H51-L16	W-U	W-P2-H80
j	--	P-P1-H42-L13	--	--	--
k	--	H-P2-H41-L14	H-P2-H46-L14	H-P2-H54	H-P2-H80
l	--	H-P1-H65-L18	H-P2-H67-L19	--	--
m	--	H-P1-H17-L07	--	H-P1-H18	H-P2-H25
n	--	--	H-P1-H33-L29	H-P2-H40	H-P2-H71
o	--	--	H-P1-H31-L09	--	--
p	--	--	P-P1-H19-L05	--	--
q	--	--	--	H-P1-H40	--
r	--	--	--	P-----H66	--
s	--	--	--	P-----H45	--
t	--	--	--	W-P1-H77	W-P1-H67
u	--	--	--	H-P1-H28	H-P1-H33
v	--	--	--	W-P1-H92	W-P2-H128
w	--	--	--	W-P1-H47	W-P1-H70
x	--	--	--	H-P1-H39	H-P1-H57
y	--	--	--	P-----H36	--
z	--	--	--	P-----H34	--
aa	--	--	--	H-P1-H35	--
bb	--	--	--	H-P1-H51	--

cc	--	--	--	H-P1-H44	--
dd	--	--	--	H-P1-H30	--
ee	--	--	--	H-P1-H18	H-P2-H54
ff	--	--	--	--	H-P1-H26
gg	--	--	--	--	H-P2-H77
hh	--	--	--	--	H-P2-H86
ii	--	--	--	--	P----H28
jj	--	--	--	--	P----H48
kk	--	--	--	--	H-P2-H74
ll	--	--	--	--	W-P1-H45
mm	--	--	--	--	H-P2-H95
nn	--	--	--	--	H-P1-H56
oo	--	--	--	--	H-P2-H94
pp	--	--	--	--	H-P1-H45
qq	--	--	--	--	H-P1-H54
rr	--	--	--	--	H-P2-H65
ss	--	--	--	--	H-P1-H38
tt	--	--	--	--	H-P1-H42

Plot 2

a	H-P2-H69-L30	H-P2-H75-L30	--	--	--
b	H-P2-H66-L23	H-P2-H66-L19	H-P2-H54-L11	H-P1-H35	H-P2-H61
c	H-P2-H44-L14	H-P1-H40-L12	H-P1-H25-L14	H-P1-H32	--
d	H-P2-H57-L23	H-P2-H75-L31	H-P2-H64-L22	H-P1-H52	H-P2-H73
e	H-P2-H31-L07	--	--	--	--
f	H-P3-H51-L30	H-P2-H67-L30	H-P2-H49-L19	H-U	H-P2-H45
g	H-P3-H66-L38	H-U	H-P2-H60-L27	H-P1-H46	H-P2-H34
h	H-P2-H45-L20	H-P3-H81-L33	H-P2-H43-L15	H-P2-H55	H-P2-H114
i	H-P2-H42-L18	H-P2-H41-L17	H-U	H-U	H-P2-H55
j	H-P2-H34-L13	H-P2-H30-L11	H-P2-H38-L10	H-P1-H20	H-P3-H93
k	H-P3-H75-L45	H-P3-H90-L53	H-P3-H57-L34	H-P2-H79	--
l	H-P3-H75-L49	H-P3-H75-L36	H-P3-H69-L27	--	--
m	--	H-P2-H63-L41	H-P2-H53-L18	H-P1-H35	--
n	--	H-P2-H69-L26	H-P2-H64-L17	--	--
o	--	H-P2-H65-L20	H-P2-H89-L38	H-P2-H86	H-P3-H105
p	--	H-P1-H34-L13	--	--	--
q	--	H-P1-H49-L20	H-P2-H51-L18	H-P1-H50	H-P1-H62
r	--	H-P1-H41-L12	H-P2-H37-L18	--	--
s	--	P-P1-H62-L14	P-P1-H82-L25	P----H38	--
t	--	P-P1-H68-L16	--	--	--
u	--	P-P1-H91-L25	P-U	P----H83	--
v	--	H-P1-H45-L10	--	--	--
w	--	W-P1-H40-L11	W-U	W-P1-H32	--
x	--	H-P2-H90-L51	H-P3-H84-L35	H-P2-H46	H-P2-H69
y	--	H-P2-H42-L11	--	--	--
z	--	H-P1-H26-L11	H-P1-H31-L08	H-P1-H29	H-P1-H41
aa	--	H-P2-H61-L32	H-U	H-P2-H58	H-P2-H51
bb	--	H-P2-H60-L24	H-P2-H38-L13	H-P1-H35	H-P2-H85
cc	--	--	H-P3-H81-L23	H-P2-H73	--
dd	--	--	H-P2-H75-L20	H-P2-H54	H-P2-H80
ee	--	--	H-P2-H50-L14	--	--
ff	--	--	P-P1-H49-L09	P----H54	P----H75
gg	--	--	P-P1-H108-L20	P----H59	--
hh	--	--	H-P2-H44-L11	H-P2-H52	H-P2-H55
ii	--	--	H-P1-H25-L04	H-P1-H19	--
jj	--	--	H-P3-H80-L30	--	--
kk	--	--	P-P1-H42-L02	P-U	P----H50
ll	--	--	W-P1-H63-L10	W-U	W-P1-H60
mm	--	--	P-P1-H49-L10	P----H54	P----H66
nn	--	--	P-P1-H38-L07	--	--
oo	--	--	H-P1-H34-L09	--	--
pp	--	--	P-P1-H31-L04	P----H46	P----H40

qq	--	--	H-P2-H57-L21	H-P1-H50	H-P2-H55
rr	--	--	--	H-P1-H35	--
ss	--	--	--	H-P1-H25	--
tt	--	--	--	H-P2-H52	--
uu	--	--	--	W-P1-H32	--
vv	--	--	--	H-P1-H29	--
ww	--	--	--	H-P1-H44	--
xx	--	--	--	P----H55	--
yy	--	--	--	P----H62	--
zz	--	--	--	H-P1-H46	--
aaa	--	--	--	--	H-P1-H40
bbb	--	--	--	--	H-P2-H75
ccc	--	--	--	--	H-P2-H25
ddd	--	--	--	--	H-P1-H53
eee	--	--	--	--	H-P2-H76
fff	--	--	--	--	P----H86
ggg	--	--	--	--	H-P1-H42
hhh	--	--	--	--	H-P2-H70
iii	--	--	--	--	H-P3-H134
jjj	--	--	--	--	P----H93
kkk	--	--	--	--	H-P2-H98
lll	--	--	--	--	H-P2-H72
mmm	--	--	--	--	H-P2-H46
nnn	--	--	--	--	W-P1-H21
ooo	--	--	--	--	H-P1-H55
ppp	--	--	--	--	H-P1-H36
qqq	--	--	--	--	H-P2-H50
rrr	--	--	--	--	P----H45
sss	--	--	--	--	W-P1-H51

Plot 3

a	H-P2-H26-L10	H-P1-H54-L14	H-P2-H41-L10	H-P1-H23	--
b	H-P2-H55-L22	H-U	H-U	H-P1-H45	--
c	H-P2-H86-L31	H-P2-H81-L31	H-P3-H44-L15	H-P2-H92	H-P2-H86
d	H-P2-H41-L14	H-U	H-P2-H53-L18	H-U	H-P1-H57
e	H-P1-H50-L14	H-U	H-P3-H89-L28	H-P2-H48	H-P2-H77
f	--	H-P1-H36-L04	H-U	H-P2-H87	--
g	--	P-P1-H67-L24	--	--	--
h	--	P-P1-H81-L17	--	--	--
i	--	H-P1-H51-L12	--	--	--
j	--	W-P1-H55-L12	--	--	--
k	--	H-P1-H45-L17	H-U	H-P1-H??	--
l	--	P-P2-H55-L32	--	--	--
m	--	H-P2-H19-L07	H-P1-H20-L17	--	--
n	--	H-P1-H52-L14	H-U	H-P2-H48	H-P2-H66
o	--	H-P2-H57-L22	--	--	--
p	--	--	H-P1-H49-L13	H-P1-H45	H-P2-H75
q	--	--	H-P1-H30-L18	H-P1-H30	H-P1-H45
r	--	--	H-P2-H38-L09	H-P1-H43	--
s	--	--	H-P2-H54-L16	H-P1-H44	--
t	--	--	H-P2-H39-L04	H-P1-H70	H-P2-H105
u	--	--	H-P1-H28-L06	H-U	H-P1-H12
v	--	--	H-P2-H29-L15	--	--
w	--	--	H-P2-H28-L01	--	--
x	--	--	H-P3-H65-L31	H-U	H-P2-H55
y	--	--	--	P----H20	--
z	--	--	--	H-P1-H24	H-P1-H47
aa	--	--	--	P----H31	P----H41
bb	--	--	--	H-P1-H22	P----H52
cc	--	--	--	H-P1-H23	--
dd	--	--	--	P----H40	--
ee	--	--	--	P----H37	--

ff	--	--	--	P----H29	--
gg	--	--	--	H-P1-H26	H-P2-H62
hh	--	--	--	P----H18	--
ii	--	--	--	--	H-P2-H56
jj	--	--	--	--	H-P2-H42
kk	--	--	--	--	H-P2-H38
ll	--	--	--	--	H-P1-H49
mm	--	--	--	--	H-P1-H44
nn	--	--	--	--	W-P2-H102
oo	--	--	--	--	P----H31
pp	--	--	--	--	H-P1-H45
qq	--	--	--	--	P----H31
rr	--	--	--	--	P----H29
ss	--	--	--	--	H leaf
tt	--	--	--	--	H-P1-H62
uu	--	--	--	--	H-P1-H23
vv	--	--	--	--	H-P2-H55
ww	--	--	--	--	H-P1-H47

Plot 4

a	H-P2-H19-L09	H-P1-H28-L13	H-P2-H24-L09	H-U	H-P1-H19
b	H-P2-H32-L11	H-P2-H36-L16	H-P2-H33-L15	H-P1-H29	H-P1-H49
c	H-P2-H31-L15	H-P2-H65-L27	H-P2-H67-L18	H-P1-H28	H-P2-H60
d	--	H-P1-H25-L08	H-P1-H21-L03	H-U	H-P2-H35
e	--	P-P1-H27-L08	P-U	P----H15	--
f	--	--	H-P3-H61-L18	H-P1-H40	H-P2-H63
g	--	--	H-P2-H59-L16	H-U	H-P1-H45
h	--	--	P-P1-H25-L06	--	--
i	--	--	H-P1-H27-L09	H-P1-H15	H-P1-H32
j	--	--	--	--	H-P1-H25
k	--	--	--	--	H-P2-H67
l	--	--	--	--	P----H22
m	--	--	--	--	H-P1-H31
n	--	--	--	--	H-P1-H50
o	--	--	--	--	P----H24
p	--	--	--	--	H-P1-H69

Plot 5

a	H-P3-H45-L28	--	--	--	--
b	P-P2-H37-L18	--	--	--	--
d	W-P1-H42-L12	--	--	--	--
e	W-P2-H49-L17	--	--	--	--
f	H-P1-H30-L11	--	--	--	--
g	H-P2-H43-L15	H-P1-H50-L16	H-P2-H43-L10	--	--
h	--	H-P1-H48-L15	H-P1-H49-L19	--	--
i	--	H-P1-H42-L15	--	--	--
j	--	H-P1-H36-L11	H-P1-H35-L14	H-P1-H45	H-P1-H41
k	--	H-sterile leaf	--	--	--
l	--	H-P2-H57-L18	--	--	--
m	--	H-P1-H20-L02	--	--	--
n	--	H-P3-H82-L36	H-P3-H140-L58	H-P2-H124	H-P2-H142
o	--	H-P2-H78-L25	H-P3-H65-L25	--	--
p	--	H-P2-H90-L50	H-P1-H29-L14	H-P1-H21	H-P2-H60
q	--	W-P1-H39-L10	--	--	--
r	--	W-P1-H41-L11	--	--	--
s	--	W-P1-H34-L09	--	--	--
t	--	H-P2-H68-L40	--	--	--
u	--	H-P1-H32-L13	H-P3-H51-L24	H-U	H-P1-H31
v	--	H-P2-H40-L15	H-P2-H38-L14	--	--
w	--	H-P2-H42-L27	--	--	--
x	--	H-P3-H74-L50	H-P1-H44-L16	H-P2-H76	H-P2-H51
y	--	H-P2-H50-L30	H-U	H-P2-H55	--

z	--	--	H-P1-H35-L11	H-P1-H18	H-P1-H46
aa	--	--	H-P1-H19-L03	H-U	H-P1-H31
bb	--	--	H-P3-H76-L29	H-P1-H48	--
cc	--	--	H-P1-H18-L03	H-P1-H21	H-P1-H12
dd	--	--	P-P1-H39-L08	P-U	P----H27
ee	--	--	H-P1-H34-L08	--	--
ff	--	--	H-P3-H68-L37	H-U	H-P2-H93
gg	--	--	H-P2-H36-L20	H-U	H-P1-H21
hh	--	--	H-P3-H56-L22	H-P2-H50	H-P2-H68
ii	--	--	H-P1-H13-L02	H-P1-H16	--
jj	--	--	H-P1-H28-L05	H-P1-H20	--
kk	--	--	P-P1-H09-L03	--	--
ll	--	--	--	H-P2-H52	--
mm	--	--	--	P----H17	--
nn	--	--	--	H-P1-H45	--
oo	--	--	--	H-P1-H21	--
pp	--	--	--	H-P2-H46	--
qq	--	--	--	H-P1-H45	--
rr	--	--	--	H-P2-H75	--
ss	--	--	--	--	P----H15
tt	--	--	--	--	W-P1-H30
uu	--	--	--	--	H-P1-H21
vv	--	--	--	--	H-P2-H85
ww	--	--	--	--	H-P2-H58
xx	--	--	--	--	H-P1-H20
yy	--	--	--	--	H-P2-H62
zz	--	--	--	--	P----H34

Plot 6

a	H-P2-H49-L15	--	--	--	--
b	H-P2-H30-L17	H-U	H-U	H-U	H-P1-H62
c	H-P2-H83-L27	--	--	--	--
d	W-P2-H89-L36	W-P2-H97-L41	W-P2-H71-L29	W----H41	W-P1-H18
e	W-P2-H44-L17	W-P2-H55-L23	W-P2-H56-L21	W----H44	W-P1-H22
f	W-P3-H83-L30	--	--	--	--
g	W-P2-H44-L22	--	--	--	--
h	W-P2-H42-L37	--	--	--	--
i	W-P2-H52-L36	--	--	--	--
j	--	H-P2-H95-L42	H-P3-H105-L39	H-P2-H88	--
k	--	H-P2-H65-L38	H-P2-H72-L35	H-P1-H66	H-P2-H80
l	--	H-P3-H80-L52	H-P3-H78-L46	H-P2-H76	H-P2-H98
m	--	H-sterile leaf	--	--	--
n	--	W-P2-H74-L26	--	--	--
o	--	H-P3-H110-L41	H-P3-H105-L34	H-P2-H57	H-P2-H96
p	--	H-P2-H66-L21	H-P2-H41-L21	H-P1-H40	--
q	--	--	H-P1-H63-L16	H-P2-H64	H-P2-H91
r	--	--	P-P1-H62-L26	--	--
s	--	--	--	H-P1-H35	--
t	--	--	--	H-P1-H41	--
u	--	--	--	--	H-P1-H29
v	--	--	--	--	H-P1-H40
w	--	--	--	--	H-P1-H48
x	--	--	--	--	H-P2-H116
y	--	--	--	--	H-P1-H64
z	--	--	--	--	H-P1-H52
aa	--	--	--	--	H-P2-H71

Plot 7

a	H-P2-H34-L12	--	--	--	--
b	H-P2-H31-L05	H-P3-H38-L20	H-P--H21-L--	--	--
c	H-P2-H20-L06	H-P2-H28-L11	--	--	--
d	H-P3-H40-L10	H-P2-H40-L14	H-P2-H30-L10	H-P1-H22	H-P1-H35

e	H-P3-H45-L22	--	--	--	--
f	H-P2-H33-L11	--	--	--	--
g	H-P2-H40-L16	H-P2-H42-L18	--	--	--
h	H-P2-H34-L13	H-P2-H26-L16	H-P2-H34-L10	H-P1-H28	--
i	H-P2-H59-L29	H-P2-H64-L26	H-P2-H68-L27	H-P1-H56	H-P2-H56
j	W-P2-H35-L14	W-P2-H42-L15	W-P1-H45-L14	W-U	W-P1-H39
k	H-P2-H64-L28	H-P2-H56-L20	--	--	--
l	H-P2-H43-L17	H-P1-H22-L05	H-P1-H30-L09	H-P1-H15	H-P1-H25
m	P-P1-H52-L15	P-P1-H50-L17	--	--	--
n	--	H-P3-H106-L38	H-P3-H68-L19	H-P2-H62	H-P2-H72
o	--	H-P2-H52-L14	--	--	--
p	--	P-P1-H17-L06	P-P1-H32-L08	P-U	P----H31
q	--	H-P1-H23-L07	H-P1-H31-L05	--	--
r	--	W-P2-H41-L20	--	--	--
s	--	H-P3-H56-L31	--	--	--
t	--	H-P1-H30-L10	--	--	--
u	--	H-P2-H43-L26	--	--	--
v	--	H-P2-H65-L31	H-P2-H41-L18	H-U	H-P1-H36
w	--	H-P1-H26-L06	H-P2-H51-L21	--	--
x	--	--	P-P1-H34-L07	--	--
y	--	--	H-P1-H16-L02	--	--
z	--	--	H-P2-H57-L23	H-P1-H40	H-P1-H33
aa	--	--	--	W-P1-H36	--
bb	--	--	--	H-P1-H40	--
cc	--	--	--	W-P1-H52	--
dd	--	--	--	--	H-P1-H13
ee	--	--	--	--	H-P1-H19
ff	--	--	--	--	P----H46

Plot 8

a	W-P4-H126-L73	--	--	--	--
b	H-P3-H96-L34	H-P2-H79-L33	--	--	--
c	H-P3-H78-L30	H-P2-H42-L11	H-P2-H72-L20	H-P1-H25	--
d	H-P3-H85-L31	--	--	--	--
e	H-P2-H49-L17	H-P2-H38-L12	H-P1-H17-L04	--	--
f	H-P2-H31-L10	--	--	--	--
g	P-P1-H10-L03	--	--	--	--
h	H-P1-H29-L16	--	--	--	--
i	H-P3-H54-L26	H-P3-H75-L32	--	--	--
j	H-P2-H39-L15	--	--	--	--
k	--	H-P3-H65-L21	H-P3-H90-L34	H-U	H-P1-H46
l	--	P-P1-H92-L23	P-U	P-U	P----H48
m	--	W-P2-H54-L16	--	--	--
n	--	W-P2-H140-L67	W-P3-H114-L53	W-P1-H120	W-P2-H53
o	--	W-P1-H49-L06	--	--	--
p	--	P-P1-H35-L05	P-P1-H44-L16	--	--
q	--	W-P1-H51-L13	W-P1-H32-L12	W----H34	W-P1-H38
r	--	W-P1-H32-L04	W-U	W-P1-H56	W-P2-H95
s	--	--	H-P1-H48-L18	H-P1-H46	--
t	--	--	H-P3-H107-L30	H-P2-H80	H-P3-H57
u	--	--	H-P2-H40-L21	H-P1-H45	--
v	--	--	W-P3-H80-L54	W----H84	W-P3-H118
w	--	--	H-P2-H41-L16	--	--
x	--	--	--	W----H58	W-P2-H80
y	--	--	--	W----H59	W-P2-H81
z	--	--	--	W-P1-H55	W-P2-H79
aa	--	--	--	W----H31	W-P2-H76
bb	--	--	--	H-P1-H60	H-P2-H92
cc	--	--	--	H-P2-H65	H-P2-H80
dd	--	--	--	H-P1-H19	H-P1-H27

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